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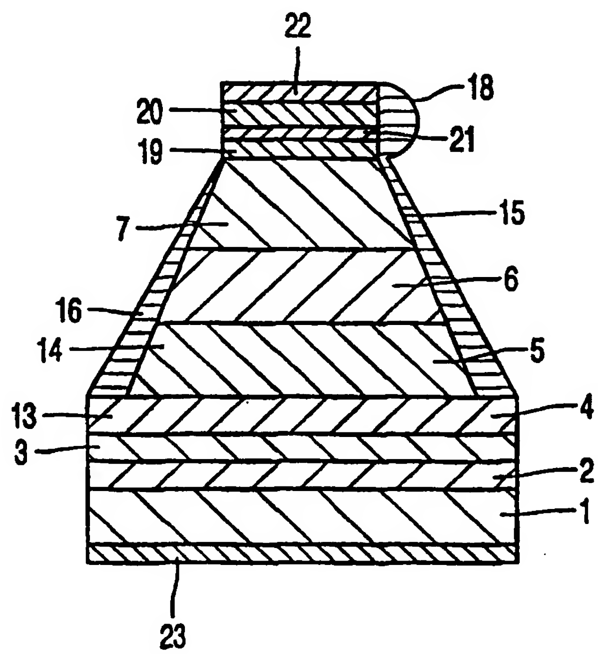
(54) Title: II-IV LASERS HAVING INDEX-GUIDED STRUCTURES

(57) Abstract

A buried-ridge II-VI laser diode has a mesa structure with portions of the active layer extending laterally from the sidewalls of the mesa and portions of the substrate extending laterally from the edges of the active layer. The sidewalls of the mesa and the extending portions of the active layer and of the substrate are covered with a layer of insulating material.



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II-IV Lasers having index-guided structures.

The United States government has certain rights in this invention pursuant to Contract No. DAAH04-94-00049 awarded by the Defense Advanced Research Projects Agency and the Department of the Army/Army Research.

BACKGROUND OF THE INVENTION

The invention relates to II-VI light emitting devices especially II-VI semiconductor lasers having index-guided structures.

Lasers of this type are known in the art. For example, such lasers are described in Haase et al. U.S. Patent 5,404,027. This patent shows a II-VI compound semiconductor laser diode comprising a semiconductor substrate of a first conductivity type a first cladding layer of II-VI semiconductor of this first conductivity type provided on the substrate, a first guiding layer of II-VI semiconductor of this first conductivity type provided on the first cladding layer, an active layer of II-VI semiconductor (quantum well layer) provided on the first guiding layer, a second guiding layer of II-VI semiconductor of a second conductivity type opposite to the first conductivity type provided on the active layer, a second cladding layer of II-VI semiconductor of the second conductivity type provided on the second guiding layer, a ridge (mesa) formed in at least one of the layers of the II-VI semiconductor and having side walls extending to the first guiding layer, a first electrode provided on the substrate at the surface thereof opposite from the second cladding layer, a semiconductor contact layer electrode provided on the surface of the ridge opposite from the substrate, a second electrode on the contact layer and a burying layer of II-VI semiconductor provided on opposite side of the ridge by forming a buried-ridge waveguide for lateral optical and current confinement.

As further shown in this patent, the burying layer of II-VI semiconductor is present on both sides of the ridge as well as on the surface of first guiding layer extending laterally from the sides of the ridge.

The sides of the ridge or mesa shown in this patent extend down to the second guiding layer, thus entirely covering the quantum well or active layer. Therefore none of this

active layer extends laterally from the sides of the ridge for this active layer and is covered by the burying layer only at its sides.

The buried-ridge lasers disclosed in this patent have been shown to emit blue-green radiation at relatively low threshold currents. It has been found, however, that these lasers suffer from the problems of relatively short lives.

These problems are considered to be caused by stacking fault defects formed both within the defined areas of the mesa and also stacking faults and other crystal defects formed outside the defined areas of the index guided mesa. As a result of these defects, there is a growth of dark lines within the active layer, originating at these defects which increase with time and actually prevent the emission of light.

The dark lines which result from defects present outside the defined area of the mesa tends to spread into the area defined by the mesa which contribute to the death of the device.

While it is not possible, at the present time, to eliminate the stacking fault defects present within the confines of the active region, it would be highly desirable to stop the growth of dark lines from defects present outside of the active region but adjacent thereto. While the laser devices described in the above-noted patent would appear to eliminate the problem of stacking faults extending from areas of the active layer present adjacent to the mesa, it has been found that the index guiding resulting from the structure is too strong to provide a beam quality that is suitable for any further optical processing.

Further, the etched edge of the active layer being immediately adjacent to the active region of the device allows high surface recombination which degrades the performance and reliability of the device. In fact, it has been found that it is very difficult to produce any useful device with a long lifetime in this manner.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a light emitting device especially a II-VI semiconductor laser wherein the effects of stacking faults (dark line defect growth) outside of the active region are significantly reduced. It is also an object of this invention to provide lasers of this type with significantly longer lives. It is an additional object of this invention to provide a method of producing such lasers.

According to the invention, a light emitting device comprises a II-VI semiconductor active layer, an active region of the active layer where light is generated with a portion of the active layer extending for a distance greater than a carrier diffusion length

beyond the active region but terminating at a distance from the active region so as to minimize the area from which defects may affect the device.

According to an important embodiment of the invention the light emitting device comprises a laser structure having a semiconductor substrate of a first conductivity type, a first cladding layer of II-VI semiconductor of this first conductivity type provided on this substrate, a first guiding layer of II-VI semiconductor provided on top of this first cladding layer, an active layer of II-VI semiconductor provided on this first guiding layer, a second guiding layer of II-VI semiconductor provided on top of the active layer, a second cladding layer of II-VI semiconductor of a second conductivity type opposite to that of the first conductivity type provided on top of the second guiding layer, an active region of the active layer which confines injected carriers and an optical field and a portion of the active layer extending laterally at least at a distance greater than a carrier diffusion length beyond the active region, but terminating at a distance from the active region so as to minimize the area from which defects may effect the device. Typically this distance is less that 100 m.

According to an additional important embodiment of the invention a laser structure is provided which comprises a substrate of a first conductivity type, a first cladding layer of II-VI semiconductor of this first conductivity type provided on top of the substrate, a first guiding layer of II-VI semiconductor provided on top of the first cladding layer, an active layer of II-VI semiconductor provided on top of the first guiding layer, a second guiding layer provided on top of a portion of the active layer, a second cladding layer of a second conductivity type opposite to that of the first conductivity type provided on top of the second guiding layer, the second guiding layer and the second cladding layer forming a mesa with side walls extending to, but not through, the active layer, a portion of the active layer extending laterally a distance more than a carrier diffusion length from the side walls but terminating at a distance from the side walls so as to minimize the area in which defects may effect the device and a burying layer of electrically insulating material covering the side walls of the mesa and exposed surfaces of the active layer.

According to another aspect of the invention laser diodes are provided in which electrode layers are provided on the surface of the mesa and on the surface of the substrate opposite to that from the first cladding layer.

A still further aspect of the invention relates to methods of forming the novel laser structure of the invention.

According to one of these methods a first cladding layer of II-VI semiconductor of a first conductivity type is provided on top of a substrate of this first conductivity type. A first guiding layer of II-VI semiconductor is provided at the top of the first cladding layer. An active layer of II-VI semiconductor is provided on top the first guiding layer. A second guiding layer of II-VI semiconductor is provided on top the active layer. A second cladding layer of II-VI semiconductor of the second conductivity type opposite to that of the first conductivity type is provided the top the second guiding layer.

Then, according to this method of the invention, a series of separated photoresist each of the width of about 2-10 μm spaced from each other about 200-400 μm are provided on top of the second cladding layer. The exposed areas of the second cladding layer are etched substantially into but not through the second cladding layer. These resists are then removed from the second cladding layer. Additional photoresists, each with the width of at least two carrier diffusion lengths less than that of the first Photoresists, are then provided at the centers of location of the first Photoresists on the remaining portions of the original surface of the second cladding layer.

Isotropic etching is then carried out of the exposed areas of the second cladding layer and of the underlying areas of the second guiding layer and active layer so as to form a series of mesas with sides extending to, but not into, the active layer, exposed surfaces of the active layer extending laterally at least one diffusion length from each side of the mesa.

The additional Photoresists are then removed. Preferably, a burying layer of electrically insulating material is then provided along the sides of the mesas and so as to cover the exposed surfaces of the active layer. As a result, a series of buried ridge waveguide II-VI laser structures are formed. The resultant laser structures are then separated from each other.

According to an additional method of the invention a first cladding layer, a first guiding layer, an active layer, a second guiding layer and a second cladding layer as employed in the first described method are provided, in the manner described therein on a substrate of a first conductivity type with the provision that the second cladding layer contains magnesium and the second guiding layer is free of magnesium. A series of Photoresists, each of a width of about to 2 to 10 m and separated from each other by about 200 to 400 m is provided on top of the second cladding layer.

In the manner described in copending Application Serial No. 08/776,731, entitled SELECTIVE ETCH FOR II-VI CONDUCTORS filed on October 7, 1996 by M.A. Haase et al.; the second cladding layer is selectively etched with an aqueous solution that includes HX, X being chlorine or bromine, with respect to the underlying second guiding layer. Here, if

desired, prior to etching with the HX solution, partial etching of the second cladding layer with an ion beam or another liquid etch may be carried out. Such preliminary etching provides the advantages of a higher resolution and a higher etch rate.

These photoresists are then removed. A second series of Photoresists are then positioned on the remaining surfaces of the second cladding layer in the manner of the first-described method and isotropic etching in the manner as described in that method is then carried out.

As a result a series of mesas are formed again with side walls extending to, but not into the active layer with exposed surfaces of the active layer extending laterally at least one diffusion length from each side of the mesa.

Here too a burying layer of an electrically insulating material is then provided along the sides of the mesas and exposed surfaces of the active layer so as to also form a series of buried ridge waveguide II-VI laser structures. These laser structures are the separated from each other.

Laser diodes may be formed by providing electrode layers on the surfaces of the mesas and on the surface of the substrate remote from the first cladding layer prior to separating the laser structures from each other.

Preferably, however laser diodes are formed by providing a contact layer on the surface of the second cladding layer prior to etching, etching to form mesas with surfaces of the contact layer, depositing electrode layers on the mesas and on the surface of the substrate remote from the first cladding layer and then separating the resultant laser structures from each other.

BRIEF DESCRIPTION OF THE DRAWING

Figs 1a-1b are cross-sectional views showing stages in the fabrication of a laser structure of the invention.

Fig 2 is a cross-sectional view of a II-VI semiconductor laser structure of the invention.

Fig 3 is a cross-sectional view of a II-VI semiconductor laser diode of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention will now be described in greater detail with reference to the figures of the drawing.

The substrate for the laser structure and laser diode of the invention may be formed of GaAs or ZnSe but preferably the substrate is formed of GaAs. The substrate may be p-doped or n-doped but preferably is n-doped.

Various II-VI materials known in the art such as Zn Mg S Se, Zn Mg Be Se, Zn Mn Be Se, Zn MgS Se may be used to form the cladding layers. Particularly suitable are the quaternary Zn Mg S Se cladding layers described in Gaines et al. U.S. Patent 5,363,395. The contents of this patent are hereby incorporated by reference.

As the material for the guiding layers Zn S Se, Zn Mg S Se, ZnMgBe Se may be used. However, the Zn S Se guiding layers of the Gaines patent are considered to be particularly suitable.

The active layer may be formed of Zn Se or Zn Cd Se or ZnCdSSe. However, the ZnCdSe active layer described in the Gaines patent is considered to be particularly suitable.

As an n-dopant for the guiding layers and cladding layers, I, F, Br, or Cl may be employed, Cl being preferred.

To form Cl ZnCl may be used. As a p-dopant for the cladding and guiding layers N may be used.

Generally, an n-type dopant, preferably Si, is employed for the substrate.

The thicknesses of each of the layers may be varied according to the desired use of the device. It has been found that particularly useful devices may be formed with a n-type cladding layer of 0.3-1 μm provided on an n-doped substrate of Ga As, an n-type guiding layer of 0.1 μm to 6.5 μm provided on this cladding layer, an active layer of 20-50A provided on this guiding layer, a p-type guiding layer of 0.1-0.5 μm provided on the active layer, and a p-type cladding layer of 0.3-1 μm provided on the p-type guiding layer.

When employed in a diode, an electrode layer such as In, Au or Pd/Au is provided on the surface of the substrate remote from the cladding layer provided thereon. An electrode layer such as Au and a contact layer are provided on the surface of the mesa. It has been found that for the contact layer the combination of an inner layer of ZnSe provided on the same mesa surface, an outer layer of ZnTe and a graded intermediate layer of ZnTeSe (with the ratio of Te to Se increasing in the direction of the ZnTe outer layer) provided between the inner and outer layer is preferred. Such a combination is described in U.S. Patent 5,548,137, the contents of which are hereby incorporated by reference.

The fabrication of a preferred embodiment of a laser structure and of a laser diode of the invention will now be described with reference to Figures 1a, 1b, 2 and 3 of the drawing which are not to scale.

Following the procedure shown in the above-noted Gaines et al. patent the following layers were subsequently deposited by MBE (molecular beam epitaxy) to form the structure as shown in Fig. 1a.:

1. A GaAs substrate 1 n-doped with Si is provided with a thin, 500-3000A thick, buffer layer of GaAs 2 n-doped with Cl. A first cladding layer 3 of 0.8 µm thick quaternary ZnMgSSe n-doped with Cl is provided on the buffer layer 2.

A first guiding layer 4 of 0.15 µm thick ternary ZnSSe n-doped with Cl is provided on the first cladding layer 3.

An undoped active layer 5 of ternary ZnCdSe of a thickness of about 20A was provided on the first guiding layer 4.

A second guiding layer 6 of 0.15 µm thick ternary ZnSSe p-doped with N+ is provided on the active layer 6.

A second cladding layer 7 of 0.8 µm thick quaternary ZnMgSSe p-doped with N+ was provided on the second guiding layer 6.

A series of photoresists 8, only two of which are shown in Fig. 1a, each of a width of 10 µm and spaced 300 µm apart are provided on the contact layer 7. The photoresists 8 were formed of OCG resist.

Etching of the exposed areas of the second cladding layer 7 was then carried out with the isotropic etch described in page 6, line 16-page 7, line 2 of Tijburg et al. U.S. Patent Application Serial No. 08/515,667 filed August 16, 1995, the contents of which are hereby incorporated by reference, at a temperature of 25°C for a period of about 4 minutes to a depth of about 0.3 µm. As a result, as shown in Fig. 1b, mesas 11 having sidewalls 10 spaced about 10 µm were formed in the second cladding layer 7. In addition, portions 9 of the second cladding layer extending laterally from the sidewalls 10 were formed.

Second photoresists 12 each of a width of 5 µm were then positioned on the centers of the remaining surfaces of the second cladding layer that form the surfaces of the mesas 11.

These exposed areas of the second of cladding layer and the underlying areas of the second guiding layer 6, the active layer 5 and the first guiding layer 4 were then isotropically etched with the same etchants for a period of about 5 minutes at a temperature of 25°C to a depth of about 0.5 µm in the first guiding layer 4 to produce mesas with side

walls extending into the first guiding layer 4 with portions 14 of the active layer 5 extending about 3 μm laterally from the side walls 15 of the mesa and portions 13 of the first guiding layer 4 extending 200 μm laterally from the edges of the portions 14, as shown in Fig. 2.

A burying layer 16 of Al_2O_3 was then deposited on the side walls of the mesa and exposed surfaces of the portions 13 and 14 to a depth of about .8 μm. The second photoresists 12 were then removed by acetone. As a result buried ridge laser structures, one of which is shown in Fig. 2, were formed.

To form laser diodes, one of which is shown in Fig. 3, a contact layer 18 was provided on the second cladding layer 7 before the photo resists 8 were provided on the second cladding layer 7. The contact layer 18 was formed of an inner 0.1 μm thick layer 19 of ZnSe in contact with the second cladding layer 7, an outer layer 20 of Zn Te of a thickness of about 500A and an intermediate layer 21 of a thickness of about 350A of ZnSeTe contacting the inner and outer layers in the intermediate layer 21 the ratio of Se to increases in the direction of the second cladding layer 7.

The photoresists 8 and subsequently the photoresists 12 were provided on the outer layer 20 and etching was carried out in the manner as described employing the same isotropic etch to form mesas in the manner as described. Buried ridge laser structures were then formed in the manner described also employing a burying layer of Al_2O_3

An electrode layer 22 of gold of a thickness of 500A was deposited on the mesas and an electrode layer 23 of Au/Pd of
1,000A thickness was deposited on the surface of the substrate.

The series of laser diodes thus formed were then separated from each other by standard methods such as cleaving.

The above-described method of forming laser diodes may be modified by forming the electrode layer 22 of gold of a thickness of 500A on the surface of the outer layer 20 of ZnTe prior to the first etching step, providing the photoresists 8 on the electrode layer 22, each photoresist separated from each other by 200 to 400 μm, ion etching to remove the exposed portions of the electrode layer 22 and the contact layer 18 and then etching with an aqueous solution of HX to remove exposed portions of the second cladding layer 7 in the manner described in page 6-page 9, line 1 of the specification of the above-noted Application Serial No. 08/726,731 Photoresists are then provided on the centers of the remaining surfaces of the second cladding layer 7. Isotropic etching of the exposed areas of the second cladding layer 7 and underlying areas of the second guiding layer 6, the active layer 5 and the first

guiding layer 3 is then carried out and a burying layer 16 provided all in the manner previously described.

Comparisons of the operating lives and other characteristics of buried ridge laser diodes of the invention and the single mesa style diodes those of the prior art are shown in the following table:

TABLE 1

Mesa Style	J_{th}(Kamps/cm^{-2})	V_{th}(Volts)	CW lifetime
Single Mesa			
Ave-	.630	7.7	24 sec (66 sec longest)
Stdev-	.16	6.4	18 sec 13 devices
DLD Barrier			
Ave-	.432	7.1	13.6 min *28.2 min longest)
Stdev-	.04	6.7	93 sec 11 devices

Jth = Threshold Current Density

Vth = Threshold Voltage

CW = Continuous Wave

Ave = Average

Stdev = Standard deviation

Single Masa = Prior art Diode

DLD Barrier = Diode of the invention

CLAIMS:

1. A light emitting device comprising a II-VI semiconductor active layer, an active region of the active layer where light is generated and at least a portion of the active layer extending for a distance greater than a carrier diffusion length beyond the active region but terminating at a distance from the active region so as to minimize the area from which defects may effect the device.

2. The light emitting device of Claim 1 wherein the II-VI semiconductor active layer terminates less than about 100 μm from the active region.

3. The light emitting device of Claim 1 or 2 and having a laser structure comprising:

(a) a semiconductor structure of a first conductivity type;

(b) a first cladding layer of II-VI semiconductor of this first conductivity type provided on the substrate;

(c) a first guiding layer of II-Vi semiconductor provided on the first cladding layer;

(d) an active layer of II-VI semiconductor provided on top of the first guiding layer;

(e) a second guiding layer of II-VI semiconductor provided on top of the active layer ;

(f) a second cladding layer of II-VI semiconductor of a second conductivity type opposite to that of the first conductivity type provided on top of the second guiding layer;

(g) an active region of the active layer which confines injected carriers and an optical field; and

(f) at least a portion of the active layer extending laterally at least a distance greater than a carrier diffusion length, but less than about 10 to 100 μm beyond the active region.

4. The light emitting device of Claim 1, 2 or 3 and having a laser structure comprising:

(a) a substrate of a first conductivity type;

(b) a first cladding layer of II-VI semiconductor of said first conductivity type; provided atop said substrate;

(c) a first guiding layer of II-VI semiconductor of said first conductivity type provided atop said first cladding layer;

(d) an active layer of II-VI semiconductor provided atop said first guiding layer;

(e) a second guiding layer of II-VI semiconductor, of a second conductivity type opposite to said first conductivity type, provided atop said active layer;

(f) a second cladding layer of II-VI semiconductor of said second conductivity type provided atop said second guiding layer;

(g) said second cladding layer and said second guiding layer forming a mesa with side walls extending at least into said first guiding layer;

(h) portions of said active layer extending laterally more than a carrier diffusion length from side walls of said mesa but less than about 100μm; and

(i) a burying layer of electrically insulating material provided along said side walls of said mesa and extending to and covering said portions of said active layer thereby forming a buried ridge waveguide for lateral optical and current confinement.

5. The light emitting device of claim 4, wherein portions of said first guiding layer extend laterally from edges of said portions of said active layer and said burying layer also extends to and covers said portions of said first guiding layer.

6. The light emitting device of claim 4 or 5, wherein said portions of said second guiding layer extend at least 2 μm from the side walls of said mesa.

7. The light emitting device of claim 4, 5 or 6 wherein the active layer extends at least 2 μm beyond the surface of said mesa.

8. The light emitting device of claim 1 being a II-VI laser diode comprising:

(a) substrate of an n-type;

(b) a first n-type cladding layer of II-VI semiconductor conductivity type provided atop said substrate;

(c) a first n-type guiding layer of II-VI semiconductor provided atop said first cladding layer;

(d) an active layer of II-VI semiconductor provided atop said first guiding layer;

(e) a second p-type guiding layer of II-VI semiconductor, or of a second conductivity type opposite to said first conductivity type, provided atop said active layer;

(f) a second p-type cladding layer of II-VI semiconductor provided atop said second guiding layer;

(g) said second cladding layer, said second guiding layer, said active layer and at least said first guiding layer forming a mesa with side walls extending at least into said first guiding layer;

(h) portions of said active layer extending laterally more than a carrier diffusion length, but less than about 100 μm from sidewalls of said mesa;

(i) portions of at least said substrate extending laterally from said edges of said active layer;

(j) a burying layer of insulating material provided along said side walls of said mesa and extending to and covering surfaces of said at least substrate and said active layer, forming a buried-ridge wave-guide for lateral optical and current confinement;

(k) a first electrode layer provided on said substrate remote from said first cladding layer;

(l) a contact layer provided on said mesa opposite to said substrate, and;

(m) a second electrode layer provided on said contact layer.

9. The light emitting device of Claim 4, 5, 6 or 7 wherein the substrate is GaAs of the first conductivity type,
the first cladding layer is a layer of ZnMgSSe of the first conductivity type,
the first guiding layer is a layer of ZnSSe of the first conductivity type,
the active layer is a layer of an undoped Zn S Se,
the second guiding layer is a layer of ZnSSe of the second conductivity type,
the second cladding layer is a layer of ZnMgSSe of the second conductivity type.

10. The light emitting device of claim 8 wherein the contact layer is formed of an inner layer of Zn Se provided on the surface of the mesa, an outer layer of ZnTe contacting the outer electrode layer and an intermediate layer of graded ZnSeTe provided between said layers of ZnSe and TnSe.

11. A method of forming a light emitting device, said method comprising;

(a) providing a first cladding layer of II-VI semiconductor of a first conductivity type atop a substrate of said first conductivity type;

(b) providing a first guiding layer of II-VI semiconductor of said first conductivity type atop said first cladding layer;

(c) providing an active layer of II-VI semiconductor atop said first guiding layer;

(d) providing a second layer of II-VI semiconductor of a second conductivity type opposite to said first conductivity type atop said active layer;

(e) providing a second cladding layer of II-VI semiconductor of said second conductivity type atop said second guiding layer;

(f) providing a series of separated first Photoresists, each of a width of 5-10 μm atop a first surface of said second cladding layer;

(g) etching exposed areas of said second cladding layer substantially into but not through said second cladding layer;

(h) removing said first resists from said second cladding layer;

(i) providing a series of second photoresists on remaining portions of said first surface;

(j) etching exposed areas of second cladding layer and underlying areas of said second guiding layer and areas of said active layer extending laterally more than 2 μm from edges of overlaying areas of said second guiding layer and said second cladding later to thereby form a mesa with sidewalls extending substantially into said first guiding and exposed surfaces of said active layer extending laterally from said sidewalls and exposed surfaces of said first guiding layer extending laterally from edges of said active layer, and;

(k) providing a burying layer of electrically insulating material along said sidewalls of said mesa and covering exposed surfaces of said active layer and said first guiding layer thereby forming a buried ridge wave-guide for lateral optical and current confinement.

12. The method of claim 11 comprising:

(a) providing a first n-type cladding layer of II-VI semiconductor of atop an n-type substrate,

(b) providing a first n-type guiding layer of II-VI semiconductor atop said first cladding layer,

(c) providing an active layer of II-VI semiconductor atop said first guiding layer,

(d) providing a second guiding layer of p-type II-VI semiconductor of atop said active layer,

(e) providing a second p-type cladding layer of II-VI semiconductor of atop said second guiding layer,

(f) providing a contact layer atop said second cladding layer,

(g) providing a series of separated first photoresists, each of a width of 5-10 μm atop a first surface of, said contact layer,

(h) etching exposed areas of said contact layer substantially into but not through said second cladding layer,

(i) removing said first resists from said contact layer,

(j) providing a series of second photoresists on remaining portions of said contact layer,

(k) etching exposed areas of said contact layer and underlying areas of said second cladding layer and said second guiding layer and areas of said active layer extending laterally more than 2μ from edges of overlaying areas of said second guiding layer and said second cladding later to thereby form a mesa with sidewalls extending substantially into said active layer and exposed surfaces of said active layer extending laterally from said sidewalls and exposed surfaces of said first guiding layer extending laterally from edges of said active layer, and;

(l) providing a burying layer of electrically insulating material along said sidewalls of said mesa and covering exposed surfaces of said active layer and said first guiding layer thereby forming a buried ridge waveguide for lateral optical and current confinement,

(m) providing electrode layers atop said mesas and on the surface of said substrate away from said first cladding layer and,

(n) and then separating the resultant series of laser diodes from each other.

13. The method of Claim 11 or 12, comprising

(a) providing a first n-type cladding layer of II-VI semiconductor of atop an n-type substrate;

(b) providing a first n-type guiding layer of II-VI semiconductor atop said first cladding layer;

(c) providing an active layer of II-VI semiconductor atop said first guiding layer;

(d) providing a second guiding layer of p-type ZnSSe atop the active layer;

(e) providing a second cladding layer of p-type ZnMgSSe atop the second guiding layer;

(f) providing a contact layer atop the second contact layer;

(g) providing a first electrode layer atop said contact layer and a second electrode layer on the surface of the substrate away from the first cladding layer;

(h) providing a series of separated first photoresists, each of a width of 1 to 10 μm, and separated form each other by 100 to 400 μm atop a first surface of the first electrode layer;

(i) etching exposed areas of the first electrode layer and underlying areas of the contact layer so as to expose areas of the second cladding layer;

(j) etching exposed areas of the second cladding layer with an aqueous solution of HX where X is chlorine or bromine so as to expose areas of the second guiding layer;

(k) removing the first photoresists from the first electrode layer;

(l) providing a series of second photoresists on the remaining portions of the second cladding layer;

(m) etching exposed areas of the second cladding layer and underlying areas of the second guiding layer and areas of the active layer extending laterally more than 2 μm from edges of overlying areas of the second guiding layer and said second cladding layer to thereby form a mesa with sidewalls extending substantially into the active layer and exposed surfaces of the active layer extending laterally from the sidewalls and exposed surfaces of the first guiding layer extending laterally from edges of the active layer;

(n) providing a burying layer of electrically insulating material along said sidewalls of said mesa and covering exposed surfaces of said active layer and said first guiding layer thereby forming a buried ridge waveguide for lateral optical and current confinement;

(o) and then separating the resultant series of laser diodes from each other.

14. The method of Claim 11, 12 or 13 wherein at least one etching is an isotropic liquid etching.

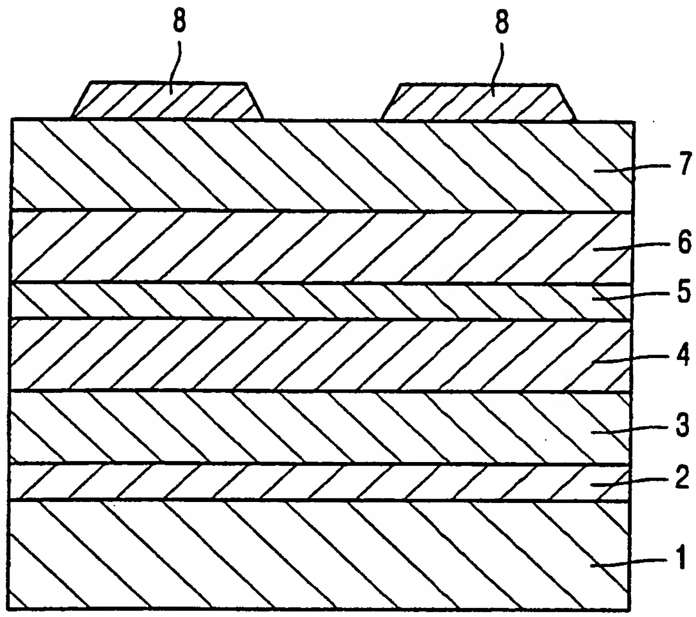

FIG. 1A

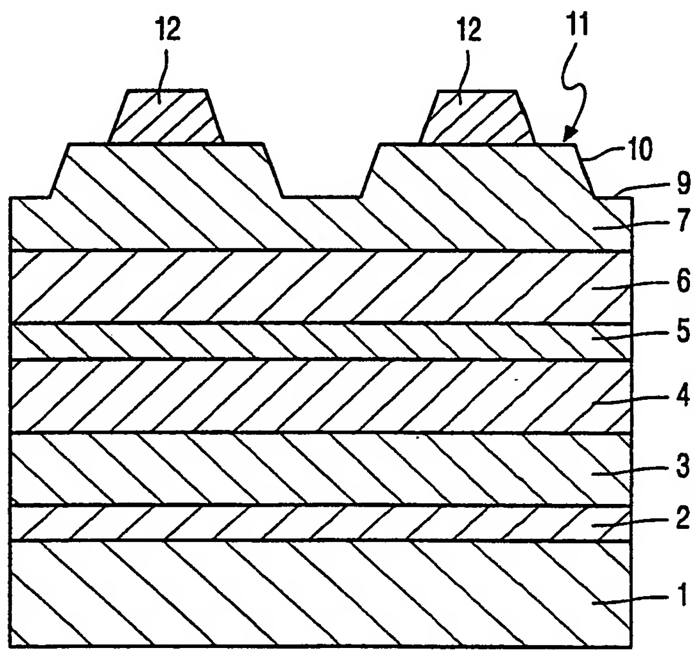

FIG. 1B

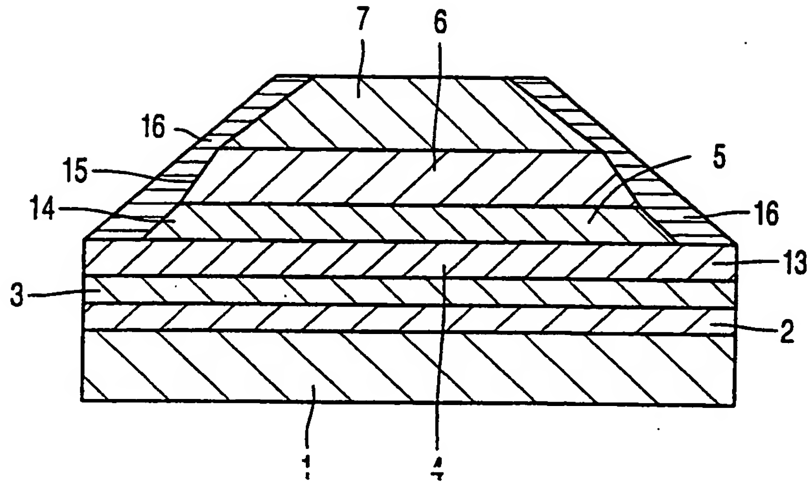

FIG. 2

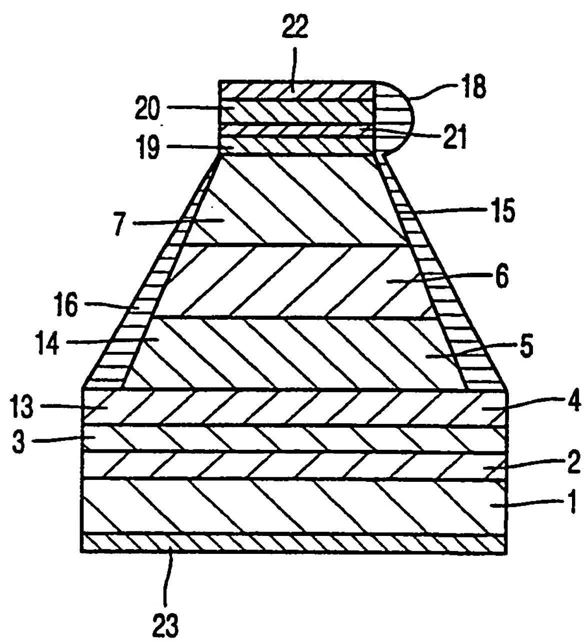

FIG. 3